Part 4 – Assembly Programming Basics

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Who am I #1

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Presentation Outline

- Intro to x86-32
- Assembly Language
- Instructions
- Stack Operations
- Calling conventions
- Demo

x86-32

- 32 bit instruction set architectures based on Intel 8086 CPU
- Address a linear address space up to 4GB
- 8, 32 bit General Purpose Registers (GPR)
- 6,16 bit Segment Registers
- EFLAGS and EIP register
- Control Registers (CR0-CR4) (16 bits)
- Memory Management Registers Descriptor Table Registers (GDTR, IDTR, LDTR)
- Debug Registers (DR0-DR7)

Registers Usage - RE

- Register
  - Storage Locations.
  - Much faster access compare to memory locations.
- EAX: Accumulator , mostly stores return values from functions (APIs)
- EBX: Base index (for use with arrays)
- ECX: Counter
- EDX: Data/general
- ESI: *Source index* for string operations.

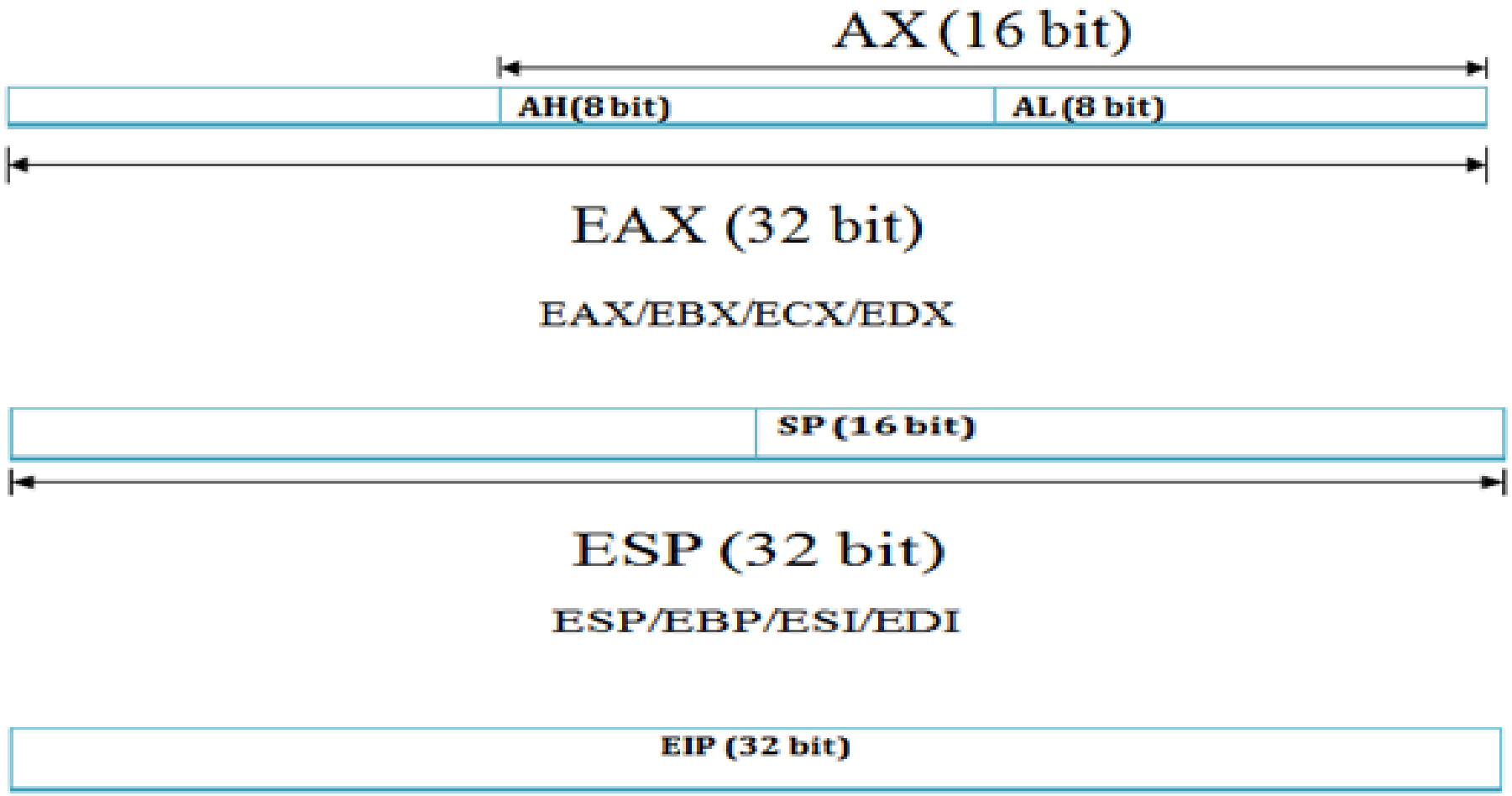
Registers Usage – RE Cont.

- EDI: *Destination index* for string operations.
- ESP: Stack pointer for top address of the stack.
- EBP: Stack base pointer for holding the address of the current stack frame.
- EIP: Instruction pointer. Holds the program counter, the next instruction address.
- Segment registers:
  - Used to address particular segments of memory (code, data, stack)

    !) CS: Code !!) SS: Stack

    !!!) ES: Extra !V) DS: Data V) FS, GS

Registers – 32 bit (X86)



(R/E)Flags Register

- Bit field of states
- Status Flags
  - Carrry (CF) : set when an arithmetic carry/borrow has been generated out of the MSB.
  - Zero (ZF) : set when an arithmetic operation result is zero and reset otherwise.
  - Sign (SF) : set when an arithmetic operation set the MSB i.e. the result value was negative.
  - Trap (TF) : when set permits operation of processor in single-step. Mostly used by debuggers.
  - Interrupt (IF) : determines whether the CPU should handle maskable hardware interrupts.
  - Direction (DF) : determines the direction (left-to-right or right-to-left) of string processing.
  - Overflow (OF) : indicates arithmetic overflow.

Assembly Language

- Low level programming language
- Symbolic representation of machine codes, constants.
- Assembly language program consist of sequence of process instructions and meta statements
- Assembler translates them to executable instructions that are loaded into memory and executed.
- Basic Structure

  [label] : opcode operand1, operand2

  opcode – mnemonic that symbolize instructions
- Example.
  - **MOV** AL, 61h => 10110000 01100001

Instructions

ADD dst, src

- Adds the values of src and dst and stores the result into dst.
- For example ADD EAX, 1

SUB dst, src

- Subtracts src value from dst and stores the result in dst.
- For example SUB EAX, 1

CMP dst, src

- Subtracts src value from dst but does store the result in dst
- Mostly used to set/reset decision making bits in EFLAGS register such as ZF
- For example CMP EAX, EBX

Instructions cont.

MOV dst, src

- Moves data from src (left operand) to destination (right operand)
- For example mov EDI, ESI

Note :

- Both operands cannot be memory locations.
- Both the operands must be of the same size

LEA dst, src

- Stands for Load Effective Address.
- Computes the effective address of src operand and stores it in dst operand.
- For example LEA ECX,[EBX + 5]

Note:

- Generally brackets denote value at memory locations.
- In case of LEA it does simple arithmetic and stores it in dst

Instructions cont.

XOR dst, src

- Performs a bitwise exclusive OR operation on the dst and src and stores the result in dst.
- Each bit of the result is 1 if the corresponding bits of the operands are different, 0 if the corresponding bit are same

Note :

- When used with same register clears the contents of the register
- Optimized way to clear the register. Better than MOV EAX, 0

Instructions cont.

REP

- Used with string operations
- Repeats a string instruction until ECX (counter register) value is equal to zero.
- For example REP MOVS byte ptr DS:[EDI], DS:[ESI]

LOOP

- Similar to loops in high level languages
- Used to execute sequence of instructions multiple times.
- For example

```
MOV ECX, 10
Test : INC EBX
       INC EAX
       LOOP  Test
```

Instructions cont.

TEST dst, src

- Performs bitwise logical and between dst and src
- Updates the Zero flag bit of the EFLAGS register
- Mostly used to check if the return value of the function is not zero
- For example TEST EAX, EAX

INT 3h

- Breakpoint instruction
- Used by debuggers to stop execution of the program at particular instruction

Instructions cont.

CALL address

- Performs two functions
  - Push address of the next instruction on stack (return address)
  - Jump to the address specified by the instruction
- For example CALL dword ptr [EAX+4]

RET

- Transfers the control to the address previously pushed on the stack by CALL instruction
- Mostly denotes the end of the function

Instructions cont.

Jump instructions

- Categorized as conditional and unconditional
- Unconditional jump instructions
  - JMP (Far Jump) – E9 – (Cross segments)
  - JMP (Short Jump) – EB – (-127 to 128 bytes)
  - JMP (Near Jump) – E9 – (in a segment)
- For example JMP EAX

- Conditional jump instructions
  - Jumps according to bit flags set in the EFLAGS register
  - JC, JNC, JZ, JNZ, JS, JNS, JO, JNO
  - Unsigned comparisons JA, JAE, JB, JBE
  - Signed comparisons JG, JGE, JL, JLE
  - Usually followed by CMP instruction

Instructions cont.

PUSH operand

- Pushes operand on the stack
- Decrements the stack pointer register by operand size
- For example PUSH EAX

POP operand

- Stores the value pointed by the stack pointer in operand
- Increments the stack pointer register by operand size
- For example POP EAX

Note: POP/PUSH EIP is an invalid instruction

PUSHF, POPF

Calling Conventions

- Describes how the arguments are passed and values returned by functions.
- Steps performed when a function is called
  - Arguments are passed to the called function
  - Program execution is transferred to the address of the called function
  - Called function starts with lines of code that prepare stack and registers for use within the function. Also known as **function prologue**.
    - For e.g.

      ```
      push ebp
      mov ebp, esp
      or with enter instruction
      ```
  - Called function ends with lines of code that restore stack and registers set initially. Also known as **function epilogue**.
    - For e.g.

      ```
      mov esp, ebp
      pop ebp
      ret
      or with leave instruction
      ```
  - Passed arguments are removed from the stack, known as stack cleanup. Can be performed by both calling function or called function depending on the **calling convention used.**

Calling conventions cont.

- __cdecl (C calling convention)
  - Arguments are passed from right to left and placed on the stack
  - Stack cleanup is performed by the caller
  - Return values are stored in EAX register
  - Standard calling convention used by C compilers

- __stdcall (Standard calling convention)
  - Arguments are passed from right to left and placed on the stack
  - Stack cleanup is performed by the called function
  - Return values are stored in EAX register
  - Standard calling convention for Microsoft Win32 API

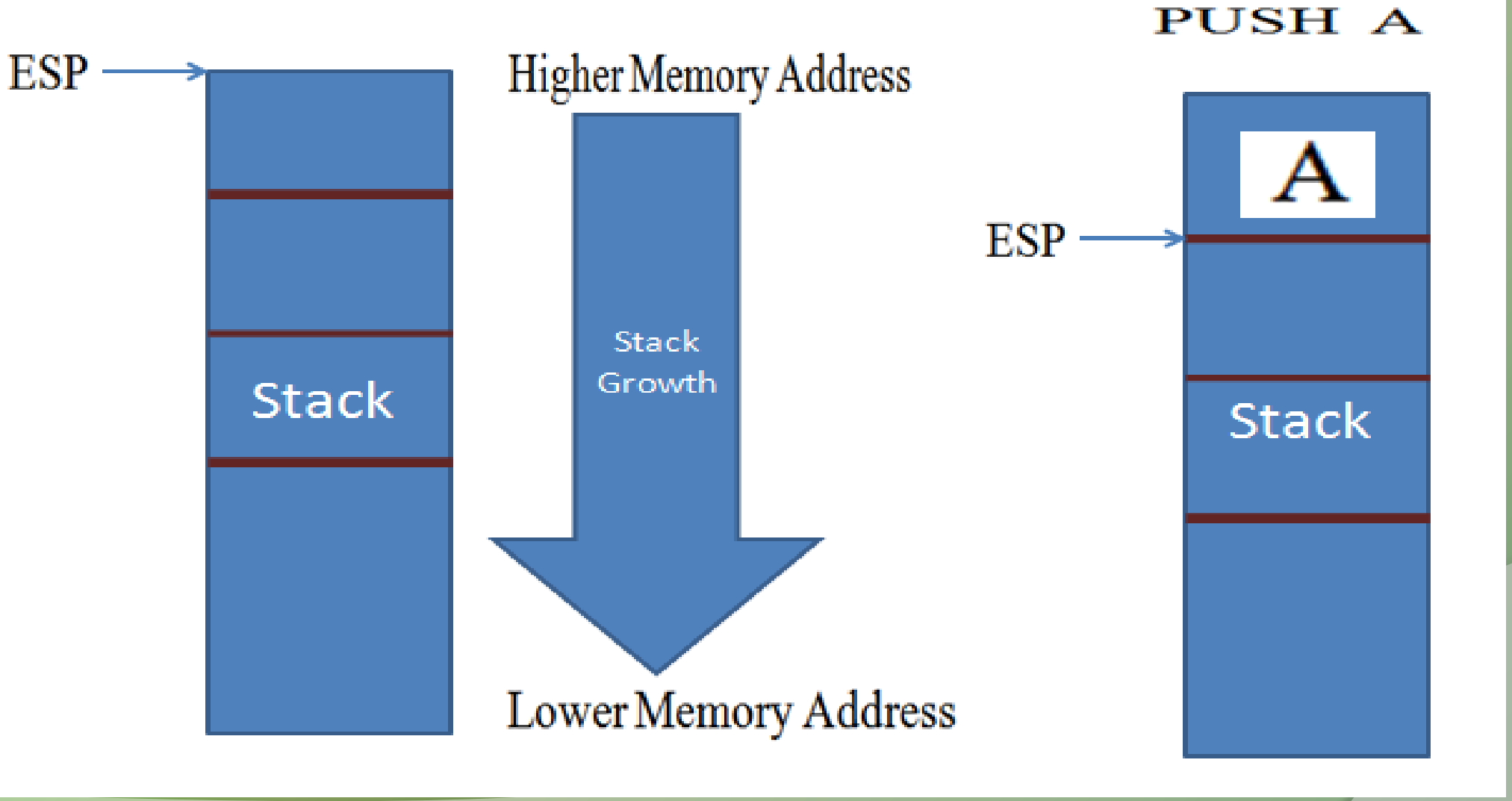
- __fastcall (Fast calling convention)
  - Arguments passed are stored in registers for faster access

- Thiscall
  - Arguments are passed from right to left and placed on the stack. this pointer placed in ECX
  - Standard calling convention for calling member functions of C++ classes

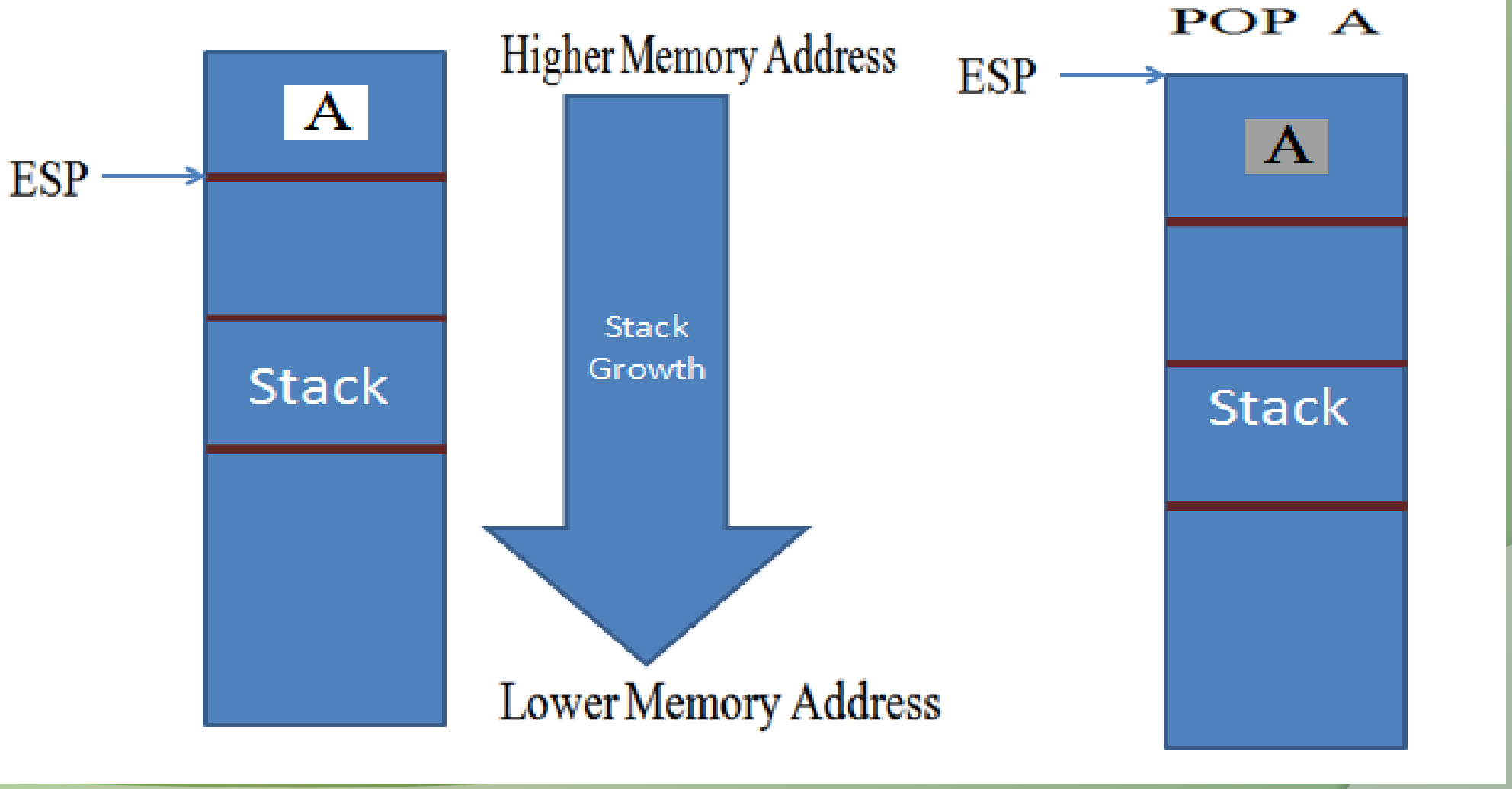
Stack operations

- Stack is a LIFO (Last In First Out) type data structure
- Stacks grows downward in memory, from **higher memory** address to **lower memory** address
- PUSH decrement the stack pointer i.e ESP
- POP Increment the stack pointer i.e ESP
- **Each function has its own stack frame**
- Function prologue setup the stack frame for each function
- **Local variable of a function are stored into its stack frame**

Stack #1


ESP
Stack
Higher Memory Address
Stack
Growth
Lower Memory Address
PUSH A
A
ESP
Stack

Stack #2


A
ESP
Stack
Higher Memory Address
Stack
Growth
Lower Memory Address
POP A
ESP
A
Stack

Stack #3

- Each function creates its own stack.
- Caller function stack: known as parent stack.
- Called function stack: known as child stack.

For e.g.

```
main(){
        sum();
}
```

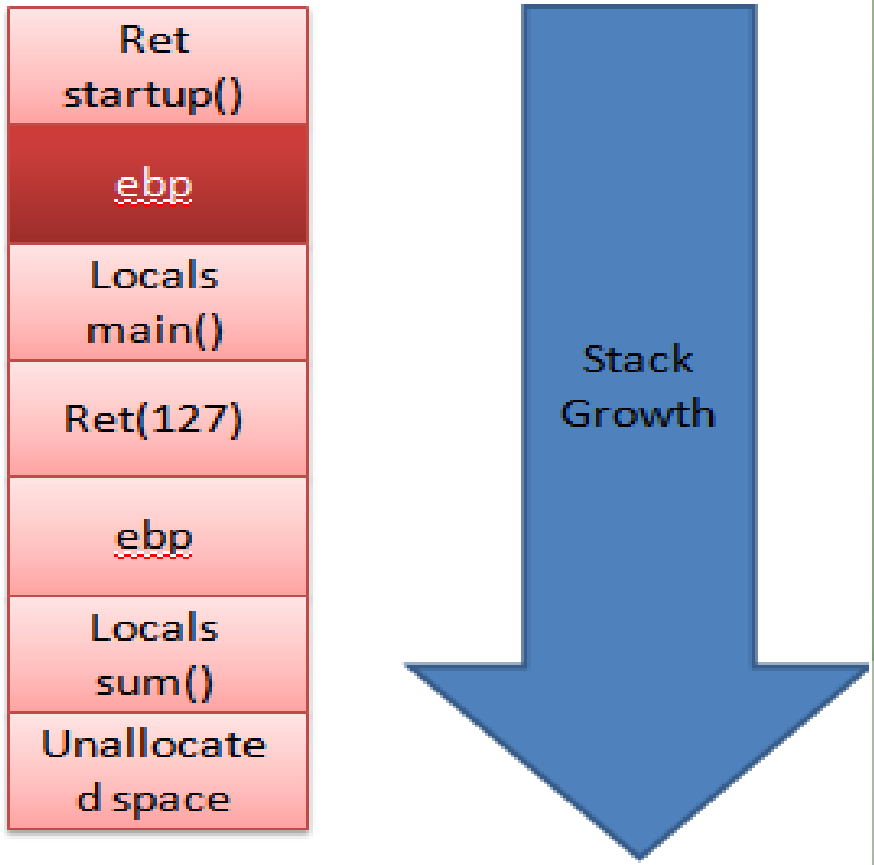
ASM Pseudo:

```
_main:
123:    push ebp
124:    mov ebp,esp
125:    sub esp,val
126:    call _sum
127:    mov esp,ebp
128:    pop ebp
129:    ret
```

* The parent and child notation is the instructor notation, technically it should be caller and callee stack frames.

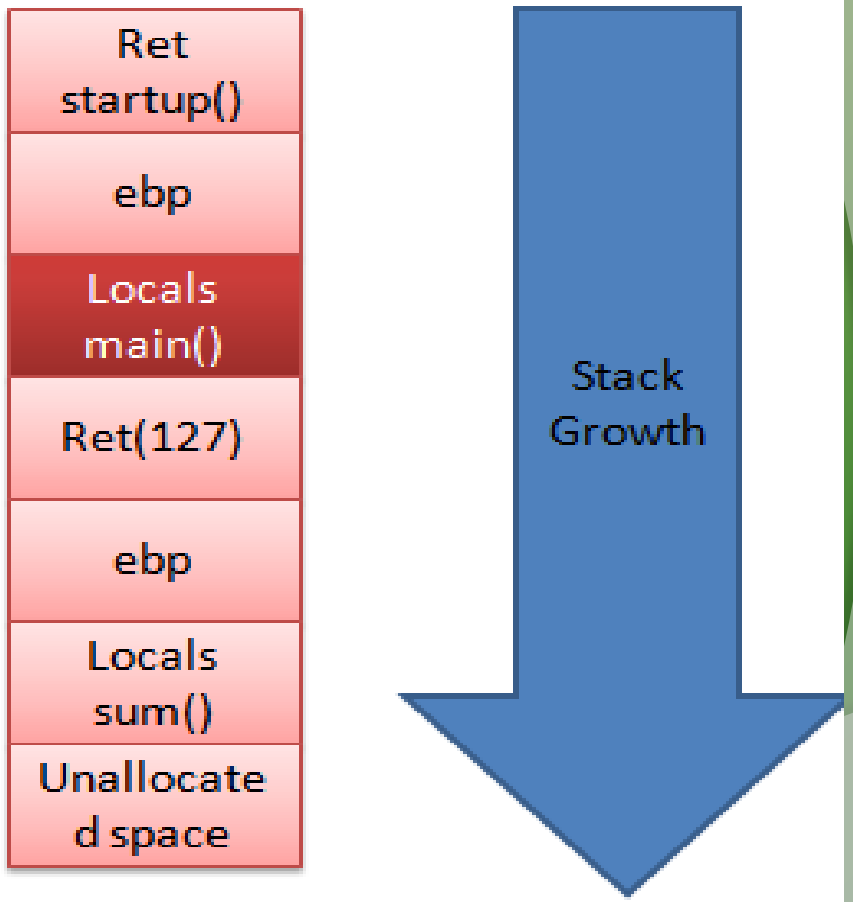
Stack #4

```
123:    push ebp
124:    mov ebp,esp
125:    sub esp,val
126:    call _sum
127:    mov esp,ebp
128:    pop ebp
129:      ret
```



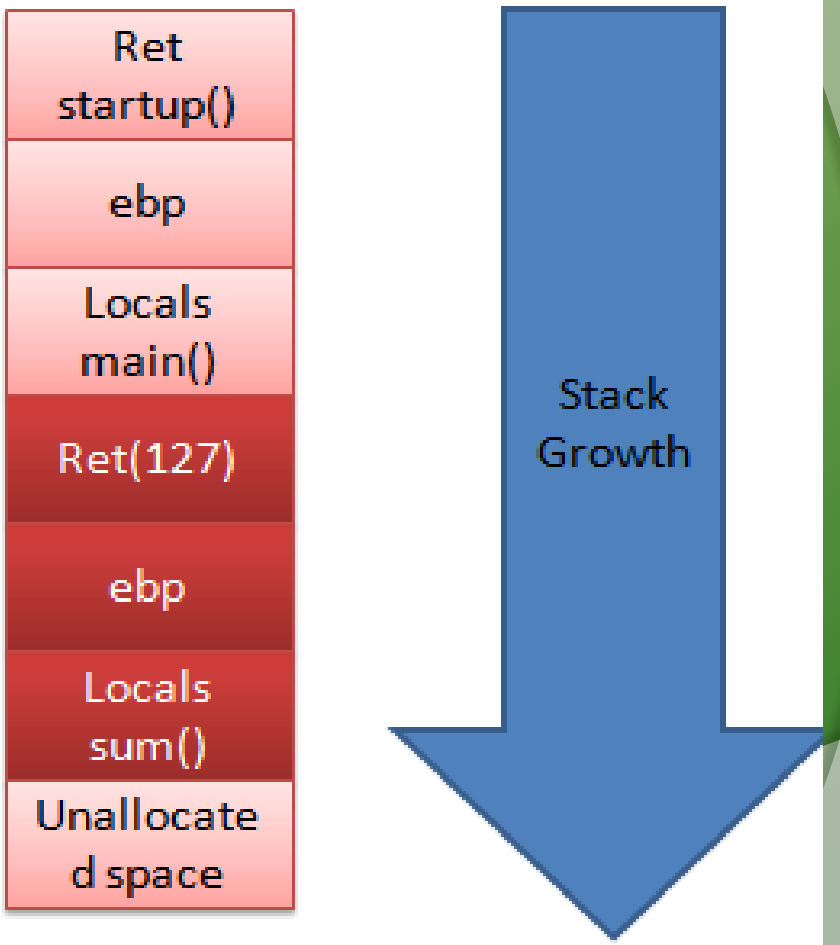
Stack #5

```
123:    push ebp
124:    mov ebp,esp
125:    sub esp,val
126:    call _sum
127:    mov esp,ebp
128:    pop ebp
129:     ret
```



Stack #6

```
123:    push ebp
124:    mov ebp,esp
125:    sub esp,val
126:    call _sum
127:    mov esp,ebp
128:    pop ebp
129:     ret
```



DEMO (Source Code)

```
#include <stdio.h>
/*
Author: Amit Malik
http://www.securityxploded.com    - Compile in Dev C++
*/
int mysum(int,int);
int main()
{
   int a,b,s;
   a = 5;
   b = 6;
   s = mysum(a,b);        // call mysum function
   printf("sum is: %d",s);
   getchar();
}
int mysum(int l, int m)   // mysum function
{
   int c;
   c = l + m;
   return c;
}
```

DEMO (Video)

http://vimeo.com/36198403

x86-64 Intro.

- 64 bit instruction set architectures based on Intel 8086 CPU
- Address a linear address space up to 16TB
- 16, 64 bit General Purpose Registers (GPR)
- 6, 16 bit Segment Registers
- RFLAGS and RIP register
- Control Registers (CR0-CR4) and CR8 (16 bits)
- Memory Management Registers Descriptor Table Registers (GDTR, IDTR, LDTR) size expanded to 10 bytes
- Debug Registers (DR0-DR7)

Reference

- Complete Reference Guide for Reversing & Malware Analysis Training

Thank You !

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